SRM VALLIAMMAI ENGINEERING COLLEGE

(Autonomous Institution)

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DEPARTMENT OF

ELECTRICAL AND ELECTRONICS ENGINEERING

QUESTION BANK

V SEMESTER

PEE602 – Hybrid Energy Technology

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SUBJECT & SUBJECT CODE: PEE602 – HYBRID ENERGY TECHNOLOGY

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UNIT I - INTRODUCTION TO HYBRID ENERGY SYSTEMS			
Hybrid Energy Systems – Need for Hybrid Energy Systems – Solar-Wind-Fuel Cell-Diesel, Wind Biomass-Diesel, Micro-Hydel-PV, Ocean and geyser energy – Classification of Hybrid Energy systems – Importance of Hybrid Energy systems – Advantages and Disadvantages - Environmental aspects of renewable energy - Impacts of renewable energy generation on the environment - Present Indian and international energy scenario of conventional and RE sources - Ocean energy, Hydel Energy – Wind Energy, Biomass energy, Hydrogen energy - Solar Photovoltaic (PV) and Fuel cells: Operating principles and characteristics - Grid codes for Hybrid Energy Systems.			
PART – A			
Q.No	Questions	BT Level	Competence	CO
1.	Define a hybrid energy system.	**BTL-4**	Understand	CO1
2.	Why is there a need for hybrid energy systems?	**BTL-1**	Remember	CO1
3.	List any two combinations used in hybrid energy systems.	**BTL-2**	Understand	CO1
4.	Mention two advantages of hybrid energy systems over standalone systems.	**BTL-1**	Remember	CO1
5.	What is the role of a fuel cell in a hybrid energy system?	**BTL-3**	Apply	CO1
6.	What is the significance of using diesel in hybrid energy systems?	**BTL-2**	Understand	CO1
7.	Give two examples of hybrid combinations using wind energy.	**BTL-1**	Remember	CO1
8.	What is a Micro-Hydel-PV hybrid system?	**BTL-3**	Apply	CO1
9.	Classify hybrid energy systems based on the type of energy sources used.	**BTL-4**	Analyze	CO1
10.	What are the main components of a solar-wind hybrid system?	**BTL-5**	Evaluate	CO1
11.	State two environmental benefits of using renewable energy.	**BTL-1**	Remember	CO1
12.	List any two environmental impacts of renewable energy generation.	**BTL-3**	Apply	CO1
13.	Define Ocean Thermal Energy Conversion (OTEC).	**BTL-2**	Understand	CO1
14.	What are the main forms of ocean energy?	**BTL-2**	Understand	CO1
15.	Mention two characteristics of solar photovoltaic cells.	**BTL-5**	Evaluate	CO1

16.	Write any two operating principles of a fuel cell.	**BTL-1**	Remember	CO1
17.	State any two applications of biomass energy.	**BTL-6**	Create	CO1
18.	List two advantages of hydrogen energy.	**BTL-1**	Remember	CO1
19.	Mention two types of hydel energy plants.	**BTL-6**	Create	CO1
20.	What is the function of a power converter in PV systems?	**BTL-4**	Analyze	CO1
21	Name two major renewable energy sources used in India.	**BTL-2**	Understand	CO1
22	Compare the contribution of conventional and renewable energy in India.	**BTL-4**	Analyze	CO1
23	What are grid codes in the context of hybrid energy systems?	**BTL-2**	Understand	CO1
24	Why is it important to follow grid codes in hybrid energy systems?	**BTL-1**	Remember	CO1
25	Mention two challenges of integrating hybrid energy systems into the grid.	**BTL-2**	Understand	CO1
PART – B				
1.	Explain the need for hybrid energy systems. Discuss with a block diagram the operation of a solar-wind-diesel hybrid system.	**BTL-2**	Understand	CO1
2.	Describe the configuration and working of a wind-biomass-diesel hybrid energy system. What are its advantages over standalone systems?	**BTL-1**	Remember	CO1
3.	With neat diagrams, explain the integration of Micro-Hydel and PV systems.	**BTL-3**	Apply	CO1
4.	Discuss the classification of hybrid energy systems with suitable examples.	**BTL-2**	Understand	CO1
5.	Describe the working of a hybrid system using Ocean Energy and Geyser Energy. What are the challenges in implementation?	**BTL-5**	Evaluate	CO1
6.	Explain the operating principles and performance characteristics of fuel cells used in hybrid energy systems.	**BTL-6**	Create	CO1
7.	Discuss the environmental aspects of renewable energy systems. Compare them with conventional energy sources.	**BTL-1**	Remember	CO1
8.	Analyse the environmental impacts of renewable energy generation. How can these impacts be mitigated?	**BTL-1**	Remember	CO1
9.	Present a detailed overview of the current Indian energy scenario. Compare it with the global renewable energy scenario.	**BTL-4**	Analyze	CO1
10.	Write a detailed note on the contribution of conventional and renewable energy sources to India's energy mix.	**BTL-1**	Remember	CO1
11.	Explain the working principle, types, and characteristics of solar photovoltaic (PV) systems.	**BTL-5**	Evaluate	CO1

12.	Describe the role of wind energy in hybrid systems. Include power extraction, components, and limitations.	**BTL-1**	Remember	CO1
13.	Discuss the generation of electricity using biomass. What are the key technological advancements in this area?	**BTL-2**	Understand	CO1
14.	Write an essay on ocean energy technologies. Explain the working of tidal and wave energy systems with diagrams.	**BTL-3**	Apply	CO1
15	Describe the process of hydrogen production for energy applications. How is it used in hybrid systems?	**BTL-4**	Analyze	CO1
16	What are grid codes? Explain their importance in the operation of hybrid energy systems.	**BTL-5**	Evaluate	CO1
17	Discuss the challenges and solutions involved in integrating hybrid renewable energy systems into the utility grid.	**BTL-1**	Remember	CO1
18	Explain the control strategies used in hybrid energy systems for efficient energy management.	**BTL-5**	Evaluate	CO1

	UNIT II - ELECTRICAL MACHINES FOR WIND ENERGY CONVERSION SYSTEMS (WECS)			
Review of reference theory fundamentals –Construction, Principle of operation and analysis: Squirrel Cage Induction Generator (SCIG), Doubly Fed Induction Generator (DFIG) - Permanent Magnet Synchronous Generator (PMSG).
PART – A
Q.No	**Questions**	**BT Level**	**Competence**	**CO**
1.	Define reference theory in the context of electrical machines.	**BTL-1**	Remember	CO2
2.	What is a rotating reference frame?	**BTL-1**	Remember	CO2
3.	State the difference between stationary and synchronous reference frames.	**BTL-1**	Remember	CO2
4.	What is the significance of Park's transformation?	**BTL-2**	Understand	CO2
5.	List two applications of Clarke's transformation.	**BTL-2**	Understand	CO2
6.	What are the benefits of using d-q axis modeling in machine analysis?	**BTL-1**	Remember	CO2
7.	State the assumptions used in dynamic modeling of electrical machines.	**BTL-4**	Analyze	CO2
8.	Define per unit system and its advantage in generator modeling.	**BTL-3**	Apply	CO2
9.	What is the constructional difference between a motor and a SCIG?	**BTL-1**	Remember	CO2
10.	How is a SCIG connected to the power system in a wind turbine?	**BTL-4**	Analyze	CO2
11.	List any two limitations of SCIG in wind energy applications.	**BTL-2**	Understand	CO2
12.	Explain why SCIG requires reactive power compensation.	**BTL-3**	Apply	CO2
13.	What are the key advantages of SCIG?	**BTL-1**	Remember	CO2
14.	Mention any two features of SCIG under variable wind speeds.	**BTL-6**	Create	CO2
15.	What is the main feature of a DFIG?	**BTL-3**	Apply	CO2
16.	Why is a partial-scale converter used in DFIG systems?	**BTL-4**	Analyze	CO2
17.	Mention two advantages of DFIG over SCIG.	**BTL-5**	Evaluate	CO2
18.	Define slip and its role in DFIG operation.	**BTL-5**	Evaluate	CO2
19.	State the function of the rotor side converter in a DFIG.	**BTL-6**	Create	CO2
20	How does DFIG support grid voltage during faults?	**BTL-5**	Understand	CO2
21	What is a permanent magnet synchronous generator (PMSG)?	**BTL-5**	Evaluate	CO2
22	List two advantages of PMSG over DFIG.	**BTL-6**	Create	CO2
23	Why does PMSG not require field excitation?	**BTL-4**	Analyze	CO2
24	Mention two control strategies used in PMSG-based wind turbines.	**BTL-6**	Create	CO2
25.	Compare the efficiency of PMSG and SCIG in wind power generation.	**BTL-1**	Remember	CO2
PART – B

1.	Explain the concept of reference theory in electrical machines. Derive the d-q axis transformation using Park's and Clarke's transformations.	BTL-3	Apply	CO2
2.	Discuss the importance of reference frame transformations in modeling and control of AC machines.	BTL-4	Analyze	CO2
3.	With neat diagrams, explain the transformation from the three-phase to two-axis (d-q) model and its application in generator analysis.	BTL-1	Remember	CO2
4.	Describe the dynamic modeling of an induction machine in the synchronous reference frame.	BTL-6	Create	CO2
5.	Explain the construction and working of the per-unit system in the context of generator modeling. Give suitable examples.	BTL-3	Apply	CO2
6.	Describe the construction and principle of operation of a Squirrel Cage Induction Generator (SCIG).	BTL-1	Remember	CO2
7.	Derive the equivalent circuit of a SCIG. Discuss its performance under constant and variable wind speed conditions.	BTL-2	Understand	CO2
8.	Explain the advantages, limitations, and control requirements of SCIG in wind energy systems.	BTL-2	Understand	CO2
9.	With a neat schematic, explain the reactive power compensation method used with SCIG in grid-connected systems.	BTL-5	Evaluate	CO2
10.	Explain the construction, working, and power flow in a Doubly Fed Induction Generator (DFIG).	BTL-4	Analyze	CO2
11.	Draw and explain the block diagram of a DFIG-based wind turbine. Describe the function of rotor-side and grid-side converters.	BTL-1	Remember	CO2
12.	Compare the DFIG with SCIG and PMSG in terms of efficiency, cost, and controllability in wind energy conversion.	BTL-4	Analyze	CO2
13.	Discuss the control strategies of DFIG under grid disturbances. How does DFIG support Low Voltage Ride Through (LVRT)?	BTL-6	Create	CO2
14.	Derive the mathematical model of DFIG in the d-q reference frame. Explain how it enables independent control of active and reactive power.	BTL-5	Evaluate	CO2
15	Explain the construction and working of a Permanent Magnet Synchronous Generator (PMSG).	BTL-5	Evaluate	CO2
16	With neat diagrams, explain the control of a PMSG-based wind energy conversion system using vector control.	BTL-4	Analyze	CO2
17	Describe the differences in design, control, and grid integration between PMSG and DFIG in wind power applications.	BTL-6	Create	CO2
18.	What are the advantages of direct-drive PMSG wind turbines over gearbox-based systems? Explain with suitable technical justifications.	BTL-3	Apply	CO2

UNIT III - POWER CONVERTERS AND ANALYSIS OF SOLAR PV SYSTEMS

Power Converters for SPV Systems - Line commutated converters (inversion-mode) - Boost and buck boost converters- selection of inverter, battery sizing, array sizing - Analysis of SPV Systems – Block diagram of the solar PV systems - Types of Solar PV systems: Stand-alone PV systems.

PART – A

Q.No	Questions	BT Level	Competence	CO
1.	What is the function of a power converter in a solar PV system?	BTL-1	Remember	CO3
2.	Define a line-commutated converter.	BTL-4	Analyze	CO3
3.	What is the role of line-commutated converters in inversion mode?	BTL-3	Apply	CO3
4.	State any two differences between a line-commutated and self-commutated inverter.	BTL-4	Analyze	CO3
5.	Define a boost converter and mention its application in SPV systems.	BTL-1	Remember	CO3
6.	What is a buck-boost converter?	BTL-1	Remember	CO3
7.	List two differences between a boost and a buck-boost converter.	BTL-1	Remember	CO3
8.	What are the advantages of using DC-DC converters in solar PV systems?	BTL-2	Understand	CO3
9.	State any two losses that occur in power converters of PV systems.	BTL-3	Apply	CO3
10.	Mention two parameters to consider when selecting a solar inverter.	BTL-1	Remember	CO3
11.	What is meant by inverter sizing in SPV systems?	BTL-2	Understand	CO3
12.	List two factors affecting battery sizing in standalone solar PV systems.	BTL-5	Evaluate	CO3
13.	What is meant by array sizing in PV systems?	BTL-4	Analyze	CO3
14.	Why is proper battery sizing important in solar PV systems?	BTL-2	Understand	CO3
15.	Mention any two types of batteries used in SPV systems.	BTL-6	Create	CO3
16.	What is the difference between series and parallel connection of PV modules?	BTL-5	Evaluate	CO3
17.	Define depth of discharge in batteries.	BTL-2	Understand	CO3
18.	List two consequences of oversizing the battery bank.	BTL-3	Apply	CO3
19.	Draw the block diagram of a basic solar PV system.	BTL-1	Remember	CO3
20.	State any two performance parameters used in analyzing a solar PV system.	BTL-6	Create	CO3
21	What is fill factor in a solar PV cell?	BTL-5	Evaluate	CO3
22	List two environmental factors that affect SPV system performance.	BTL-2	Understand	CO3
23	What is a stand-alone PV system?	BTL-3	Apply	CO3
24	Mention two differences between grid-connected and stand-alone PV systems.	BTL-1	Remember	CO3
25	Name two applications of stand-alone solar PV systems.	BTL-1	Remember	CO3

PART – B				
1.	Explain the construction, working, and applications of a line-commutated converter in inversion mode in SPV systems.	**BTL-3**	Apply	CO3
2.	With neat diagrams, describe the working of a boost converter. Derive the expression for output voltage in continuous conduction mode.	**BTL-3**	Apply	CO3
3.	Explain the operation of a buck-boost converter. Compare it with buck and boost converters.	**BTL-1**	Remember	CO3
4.	Discuss the role of DC-DC converters in solar PV systems. How do they enhance efficiency and power regulation?	**BTL-2**	Understand	CO3
5.	Compare different types of inverters used in SPV systems. Explain the criteria for inverter selection with examples.	**BTL-2**	Understand	CO3
6.	Explain the step-by-step procedure for sizing the battery bank in a stand-alone PV system.	**BTL-2**	Understand	CO3
7.	With suitable assumptions, explain how to perform array sizing in a solar PV system.	**BTL-1**	Remember	CO3
8.	Discuss the impact of oversizing and undersizing batteries and arrays in SPV systems. Provide supporting calculations.	**BTL-4**	Analyze	CO3
9.	Write detailed notes on the types of batteries used in PV systems and compare them based on efficiency, cost, and life span.	**BTL-4**	Analyze	CO3
10.	Draw and explain the block diagram of a typical solar PV system. Describe the function of each block in detail.	**BTL-1**	Remember	CO3
11.	Analyze the performance of a solar PV system under varying irradiance and temperature conditions.	**BTL-1**	Remember	CO3
12.	Explain the electrical characteristics of a PV cell. Derive expressions for open-circuit voltage, short-circuit current, and maximum power point.	**BTL-4**	Analyze	CO3
13.	Describe the I-V and P-V characteristics of a solar panel. How are they affected by irradiance and temperature?	**BTL-4**	Analyze	CO3
14.	Compare stand-alone and grid-connected PV systems in terms of configuration, control, and application.	**BTL-6**	Create	CO3
15	Explain the configuration and working of a stand-alone solar PV system. Provide design considerations and examples.	**BTL-4**	Analyze	CO3
16	Describe the types of loads and storage requirements in a stand-alone PV system. How is energy management handled?	**BTL-4**	Analyze	CO3
17	Discuss the challenges and solutions in designing reliable stand-alone PV systems for rural electrification.	**BTL-6**	Create	CO3
18.	Explain the importance of power electronics in modern solar PV systems. Discuss the future trends in converter technologies for renewable energy.	**BTL-2**	Understand	CO3

UNIT IV- ANALYSIS OF POWER CONVERTERS FOR HYBRID ENERGY SYSTEMS

Introduction to Power Converters – Stand-alone Converters -AC-DC-AC converters: uncontrolled rectifiers, PWM Inverters - Bi-Directional Converters - Grid-Interactive Inverters - Matrix converter – Merits and Limitations.

Part-A

Q.No	Questions	BT Level	Competence	COs
1	Define a power converter.	**BTL-1**	Remember	CO4
2	What is the function of a stand-alone power converter?	**BTL-1**	Remember	CO4
3	Name any two types of power converters used in renewable energy systems.	**BTL-2**	Understand	CO4
4	What is an AC-DC-AC converter? Give one example.	**BTL-3**	Apply	CO4
5	List two applications of stand-alone converters.	**BTL-4**	Analyze	CO4
6	What is an uncontrolled rectifier?	**BTL-5**	Evaluate	CO4
7	List two differences between controlled and uncontrolled rectifiers.	**BTL-1**	Remember	CO4
8	Why are uncontrolled rectifiers commonly used in power converters?	**BTL-1**	Remember	CO4
9	What are the input and output of an AC-DC-AC converter?	**BTL-2**	Understand	CO4
10	Mention one drawback of uncontrolled rectifiers.	**BTL-2**	Understand	CO4
11	What is meant by PWM inverters?	**BTL-3**	Apply	CO4
12	List two advantages of using PWM inverters.	**BTL-4**	Analyze	CO4
13	Define pulse width modulation (PWM).	**BTL-5**	Evaluate	CO4
14	Why are PWM inverters preferred in SPV systems?	**BTL-6**	Create	CO4
15	What are the key components of a PWM inverter?	**BTL-1**	Remember	CO4
16	What is a bi-directional converter?	**BTL-1**	Remember	CO4
17	List one application of a bi-directional converter in renewable energy systems.	**BTL-2**	Understand	CO4
18	Mention two modes of operation of a bi-directional converter.	**BTL-3**	Apply	CO4
19	Why are bi-directional converters essential in energy storage systems?	**BTL-4**	Analyze	CO5
20	Give one example where power flows in both directions in a system.			
21	What is a grid-interactive inverter?	**BTL-3**	Apply	CO5
22	List two features of a grid-interactive inverter.	**BTL-4**	Analyze	CO5
23	Why is anti-islanding protection used in grid-interactive inverters?	**BTL-5**	Evaluate	CO5
24	State any two differences between a grid-tied and a stand-alone inverter.	**BTL-6**	Create	CO5
25	What is the role of synchronization in grid-interactive inverters?	**BTL-2**	Understand	CO4

Part-B

1	Explain the classification of power converters used in renewable energy systems. Describe the need and importance of stand-alone converters.	**BTL-1**	Remember	CO5
2	Describe the working of a stand-alone power converter with a neat block diagram. What are the key design considerations?	**BTL-1**	Remember	CO5

3	Compare stand-alone converters with grid-interactive converters in terms of operation, application, and control.	**BTL-2**	Understand	CO5
4	Explain the operation of an AC-DC-AC converter with circuit diagram and waveform. Discuss its role in wind and solar systems.	**BTL-3**	Apply	CO5
5	With a neat circuit, explain the working of an uncontrolled rectifier. Derive the average output voltage.	**BTL-4**	Apply	CO5
6	Differentiate between controlled and uncontrolled rectifiers. Describe their advantages and applications in renewable energy systems.	**BTL-5**	Analyze	CO5
7	What is a PWM inverter? Explain its operation using unipolar and bipolar modulation techniques.	**BTL-1**	Remember	CO5
8	Draw the circuit of a PWM inverter and describe its advantages in solar PV applications.	**BTL-2**	Understand	CO5
9	Discuss the role of PWM inverters in reducing harmonic distortion. Include relevant waveforms and analysis.	**BTL-4**	Analyze	CO5
10	Explain the working principle of a bi-directional converter. Discuss its application in battery charging and discharging cycles.	**BTL-1**	Remember	CO5
11	With a neat diagram, explain how bi-directional converters operate in both buck and boost modes.	**BTL-2**	Understand	CO5
12	Describe the control strategy of a bi-directional converter in a hybrid energy system with storage integration.	**BTL-3**	Apply	CO5
13	Explain the operation of grid-interactive inverters with block diagram. Discuss their synchronization with grid voltage.	**BTL-4**	Analyze	CO5
14	Discuss the protection features required in grid-interactive inverters. How is anti-islanding implemented?	**BTL-6**	Create	CO5
15	Compare grid-tied inverters with stand-alone inverters. Explain their roles in smart grid and microgrid applications.	**BTL-3**	Apply	CO5
16	What is a matrix converter? Explain its principle of operation with advantages and limitations.	**BTL-4**	Analyze	CO5
17	Describe the control techniques used in matrix converters. How do they differ from traditional AC-DC-AC converters?	**BTL-6**	Create	CO4
18.	Compare the performance of different converter types (PWM, matrix, bi-directional, etc.) in terms of efficiency, control, and application.	**BTL-5**	Evaluate	CO4

UNIT V- CASE STUDIES FOR HYBRID RENEWABLE ENERGY SYSTEMS

Hybrid Systems- Range and type of Hybrid systems – Performance Analysis – Cost Analysis – Case studies of Diesel-PV, Wind-PV-Fuel-cell, Micro-hydel-PV, Biomass-Diesel-Fuel-cell systems.

Part-A

Q.No	Questions	BT Level	Competence	COs
1	What is a hybrid energy system?	BTL-1	Remember	CO5
2	List two examples of renewable-nonrenewable hybrid systems.	BTL-2	Understand	CO5
3	Mention any two benefits of hybrid energy systems.	BTL-3	Apply	CO5
4	Define a stand-alone hybrid energy system.	BTL-4	Analyze	CO5
5	What are the main components of a typical hybrid system?	BTL-1	Remember	CO5
6	Name two types of hybrid combinations using solar PV.	BTL-2	Understand	CO5
7	List two challenges in designing a hybrid energy system.	BTL-3	Apply	CO5
8	Mention two reasons for preferring hybrid systems over conventional ones in rural areas	BTL-6	Create	CO5
9	What is a Diesel-PV hybrid system?	BTL-4	Analyze	CO5
10	Name the renewable sources used in a Wind-PV-Fuel cell hybrid system.	BTL-1	Remember	CO5
11	What is the role of a fuel cell in hybrid energy systems?	BTL-2	Understand	CO5
12	Define a Micro-hydel-PV hybrid system.	BTL-4	Analyze	CO5
13	Mention any two features of Biomass-Diesel-Fuel cell hybrid systems.	BTL-1	Remember	CO5
14	Give two examples of hybrid systems used for off-grid applications.	BTL-2	Understand	CO5
15	What are the performance indicators of a hybrid energy system?	BTL-3	Apply	CO5
16	List two parameters used in evaluating system efficiency.	BTL-1	Remember	CO5
17	Why is load matching important in performance analysis of hybrid systems?	BTL-5	Evaluate	CO5
18	Name any two software tools used for hybrid system simulation.	BTL-6	Create	CO5
19	Define Levelized Cost of Energy (LCOE).	BTL-1	Remember	CO5
20	List any two factors affecting the cost analysis of hybrid energy systems.	BTL-5	Evaluate	CO5
21	Why is economic feasibility analysis crucial for hybrid systems?	BTL-5	Evaluate	CO5
22	What is payback period in hybrid system economics?	BTL-6	Create	CO5
23	What is the advantage of using Diesel-PV hybrid systems in remote villages?	BTL-1	Remember	CO5
24	Mention one real-world application of a Wind-PV-Fuel cell hybrid system.	BTL-5	Evaluate	CO5
25	List two benefits observed from Micro-hydel-PV hybrid system case studies.	BTL-2	Understand	CO5

	Part-B			
1	Explain the need for hybrid energy systems. Classify them based on resource types and configurations.	**BTL-1**	Remember	CO5
2	Describe various types of hybrid systems involving renewable and non-renewable energy sources with neat block diagrams.	**BTL-3**	Apply	CO5
3	Compare grid-connected and stand-alone hybrid systems. Discuss their advantages and limitations.	**BTL-6**	Create	CO5
4	With a neat schematic, explain the working of a Diesel-PV hybrid energy system. Discuss its advantages and limitations.	**BTL-1**	Remember	CO5
5	Describe the configuration and operation of a Wind-PV-Fuel Cell hybrid energy system. How is load sharing managed?	**BTL-3**	Apply	CO5
6	Explain the design and components of a Micro-hydel-PV hybrid system. Include power management strategies.	**BTL-2**	Understand	CO5
7	Discuss the Biomass-Diesel-Fuel Cell hybrid system. Explain its working and highlight environmental benefits.	**BTL-4**	Analyze	CO5
8	What are the key performance indicators of a hybrid energy system? Explain each with relevance to real-time operation.	**BTL-1**	Remember	CO5
9	Explain the steps involved in the performance analysis of a hybrid energy system. Use examples and graphical data.	**BTL-2**	Understand	CO5
10	How does resource variability affect hybrid system performance? Suggest optimization methods.	**BTL-6**	Create	CO5
11	Explain the methodology for cost analysis of hybrid energy systems. Discuss capital, O&M, and life-cycle costs.	**BTL-2**	Understand	CO5
12	What is Levelized Cost of Energy (LCOE)? How is it used to compare hybrid energy systems?	**BTL-4**	Analyze	CO5
13	Discuss the role of economic and financial factors (like payback period, IRR, and NPV) in assessing the feasibility of hybrid systems.	**BTL-1**	Remember	CO5
14	With an example, perform a comparative cost analysis of Diesel-only vs. Diesel-PV hybrid systems.	**BTL-4**	Analyze	CO5
15	Describe the steps involved in the design of a hybrid energy system for a remote community. Include load estimation and source selection.	**BTL-4**	Analyze	CO5
16	Discuss the challenges and solutions in the integration of multiple renewable sources in a hybrid setup.	**BTL-1**	Remember	CO5
17	Explain the use of software tools (e.g., HOMER, PVsyst) in simulating and optimizing hybrid energy systems.	**BTL-4**	Analyze	CO5
18	Discuss the environmental and sustainability aspects of hybrid energy systems. How do hybrid systems contribute to reducing carbon footprint and improving energy access in rural areas? Illustrate with examples.	**BTL-5**	Analyze	CO5

Course Outcome
- Ability to analyze the impacts of hybrid energy technologies on the environment and demonstrate them to harness electrical power.
- Ability to select a suitable Electrical machine for Wind Energy Conversion Systems and simulate wind energy conversion system.
- Ability to design the power converters such as AC-DC, DC-DC, and AC-AC converters for SPV systems.
- To get adequate knowledge to analyze the power converters such as AC-DC, DC-DC, and AC-AC converters for Hybrid energy systems.
- . To interpret the hybrid renewable energy systems.